Thoracic Outlet Syndrome

WHO GIVES A TOS?

If you have a patient with pain, numbness and/or weakness in their neck, shoulder and/or arm, thoracic outlet syndrome (TOS) could be the cause. However, it is hard to diagnose and therefore probably hugely underreported. This article takes you through all the stages for suspecting, diagnosing and treating TOS, so that you can make a massive difference to the life of patients who may have been suffering for some time. Read this article online https://bit.ly/3KFLLv7

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Well, we should all give a toss for the poor individuals suffering with unnecessary symptomology, and who are becoming frustrated, angry and depressed at the perceived lack of end to the pain, numbness and weakness in their neck, shoulder and arm. Thoracic outlet syndrome (TOS) has traditionally been a diagnosis derived through exclusion of any other condition. It can take patients up to 60 months (5 years) with symptomatic TOS to gain an appropriate diagnosis. By this stage they have seen, on average, six different specialists or doctors or therapists. They have often had at least one surgery with no relief from their symptoms or temporary relief only to have the symptoms return. Some athletes have had to stop participating in their sport as a result of their unresolved condition. These are shocking facts. It is known that TOS is a cluster of pain with neurological and vascular deficits that range from intermittent to permanent impairments. It is also known that presentation of these symptoms varies from patient to patient. It is often difficult to specifically pinpoint the site of compression, and radiological and electrophysical testing results can present as normal. Some patients have no symptoms at rest, whereas others are in constant pain. So what exactly can you – the clinician – look for during an assessment to assist with diagnosis and where do you go from there? Once the correct diagnosis is made then the logic to choose manual therapy techniques and exercises that release and 'open' the thoracic outlet makes sense. Previously, incorrect or missed diagnosis, unnecessary surgery and physical therapy directed at other structures has led to dissatisfied customers. Patients can get written off as being 'difficult' when your clinical hypothesis doesn't match any investigations. You may even attempt to 'explain their pain away' with a central sensitisation pain model. Remember, many patients have had symptoms for years and years, and the huge problem is that you're not simply dealing with something that may have been relatively easy to sort out, but now a complexity has developed with chronic pain, modification in terms of movement patterns, posture and weakness in the upper quadrant.

Introduction

TOS constitutes a group of potentially disabling conditions believed to be caused by compression of neurovascular structures supplying the upper extremity (1*). The thoracic outlet is an anatomical area in the lower neck, between the clavicle and the first rib. It can be defined as a group of three spaces through which several important neurovascular structures pass (described in more detail below), including the brachial plexus, subclavian artery and subclavian vein. Compression of this area instigates a constellation of distinct symptoms, which can include upper-extremity pallor, paraesthesia, weakness, muscle atrophy and pain (2*).

Based on the principal anatomic structures involved and the resultant clinical syndromes, three distinct types of TOS exist: neurogenic (nTOS), venous (vTOS), and arterial (aTOS) (1*). Diagnosis, treatment and outcomes vary across the different types of TOS and hence must be reported as separate entities (1*). What is more, neurovascular compression can potentially occur at three different anatomic levels: the interscalene

●● IT CAN TAKE PATIENTS UP TO 5 YEARS WITH SYMPTOMATIC TOS TO GAIN AN APPROPRIATE DIAGNOSIS ●●

triangle, the costoclavicular space, or the pectoralis minor space (2*).

nTOS is by far the most common of the three types of TOS, representing about 95% of cases (Video 1) (2*). Here, the brachial plexus trunks or cords, originating from nerve roots C5 to T1, are involved. nTOS can be further divided into true or symptomatic TOS (symptomatic TOS may also be referred to in the literature as 'disputed TOS'). Symptomatic TOS constitutes over 80% of all neurogenic TOS cases. The symptoms of true and symptomatic nTOS are largely the same, although patients with symptomatic nTOS have no radiological or electrophysical abnormality in their objective screening tests (3*,4*,5*).

Thought to be initiated by brachial plexus compression or irritation at the scalene triangle or pectoralis minor space, neurogenic symptoms are the most common. Potential manifestations of nTOS include (individually or a combination of) local pain, upper limb neurologic symptoms and tenderness at the affected areas (1*).

nTOS can be difficult to manage, in part because of non-specific symptoms, poorly understood pathophysiologic mechanisms, limited objective testing procedures, and potential overlap with other clinical disorders, as well as an absence of well-defined or consistently applied criteria for diagnosis and treatment. This can lead to missed diagnosis, unnecessary surgery and highly variable management (1*). As the most common type of TOS, this article will focus on the clinical presentation, diagnosis and management of nTOS.

Basic Anatomy and Pathophysiology

The thoracic outlet lies at the base of the neck, consists of the first rib and adjacent structures, and extends to the axilla. The symptoms of TOS arise from compression of the brachial plexus nerves, subclavian artery and vein (1*).

Table 1 describes the anatomical spaces and their contents where compression of nerves and vasculature occur. For an image of the anatomy involved, see Figure 1: Thoracic outlet and relevant anatomy in Jones et al. (Link 1) (2*).

Numerous mechanisms elicit the characteristic pathology of TOS, including anatomical variations, trauma, and repetitive motions or habits. Of the many anatomic variations that incite TOS, the presence of a cervical rib places patients at a higher risk of nTOS, with up to 20% of nTOS cases attributable solely to this cause (2*,5*). Congenital variations in musculature, for example supernumerary scalene muscle, have also been reported to cause TOS (2*).

Table 1: Anatomic spaces of thoracic outlet syndrome
Adapted from Jones MR et al. Thoracic outlet syndrome: a comprehensive review of pathophysiology, diagnosis, and treatment. Pain and Therapy 2019;8(1):5–18 (2*)

	Compartment	Borders	Contents
First/most medial compartment	Interscalene triangle	**Anterior:** anterior scalene muscle **Posterior:** middle scalene muscle **Inferior:** first rib	Brachial plexus Subclavian artery
Second compartment	Costoclavicular space	**Anterior:** subclavius muscle **Inferoposterior:** first rib and anterior scalene muscle **Superior:** clavicle	Brachial plexus Subclavian artery Subclavian vein
Third compartment	Subcoracoid space	**Anterior:** pectoralis minor muscle **Posterior:** ribs 2–4 **Superior:** coracoid	Brachial plexus Axillary artery Axillary vein

Video 1: Neurogenic Thoracic Outlet Syndrome Diagnosis | nTOS (Courtesy of YouTube user Physiotutors)
https://youtu.be/iHP0F3flLzY

Traumatic events are typically high velocity, for example a motor vehicle accident or fall from a mountain bike. Whiplash injuries have a known association with nTOS, especially in patients presenting with a cervical rib. Haemorrhage, hematoma or displaced fracture can directly compress the nerves or vasculature. A midshaft clavicular fracture is a common cause of TOS. Fibrosis can develop some time after the initial insult/injury and then produce symptoms (2*,5*).

Repetitive motions, be it at work or sport, can lead to muscle hypertrophy, muscle imbalance, and poor postural alignment that may contribute to compression. An overuse injury due to repetitive movements can cause swelling, minor haemorrhage and subsequent fibrosis, which can also account for symptom development (2*). Tumours and malignancies within the thoracic outlet should also be remembered as possible culprits to producing TOS symptoms (2*,5*).

In an athlete, the underlying mechanism of nTOS is an ongoing

THORACIC OUTLET SYNDROME (TOS) HAS TRADITIONALLY BEEN A DIAGNOSIS DERIVED THROUGH EXCLUSION OF ANY OTHER CONDITION process of repetitive injury leading to fibrosis and hypertrophy of the scalene or pectoralis minor muscles, followed by scar deposition onto the brachial plexus nerves themselves. This may be exacerbated by predisposing anatomical factors such as musculotendinous abnormalities or cervical ribs (6*).

Diagnosis and Clinical Presentation

Thoracic outlet syndrome is actually not a rare disorder. Studies have reported its incidence ranging from 3 to 80 per 1000 (5*). The diagnosis of TOS remains disputed as there is no standard objective test to confirm clinical impressions. Traditionally, it has been a 'diagnosis of exclusion'. Hence, it is unclear whether the current epidemiologic data underestimate (or overestimate) the condition. TOS usually develops in patients between 20 and 50 years old and is more common in women (5*). The symptoms can be severe and debilitating, and is frequently misdiagnosed as radicular pain, other entrapment syndromes, or muscle- or tendon-origin pain. Treatment will vary according to the type of TOS; however, the appropriate treatment can produce good outcomes in individuals, hence the importance of accurate and early diagnosis (5*).

As mentioned in Illig et al. (1*), nTOS should be defined/diagnosed by the presence of *three of the following four criteria*:

1. Local findings

a. This criterium includes symptoms consistent with irritation or inflammation at the site of compression (within one of the three thoracic outlet compartments, eg. the scalene triangle), along with symptoms due to referred pain in the areas near the thoracic outlet. Patients may complain of pain in the chest wall, axilla, upper back, shoulder, trapezius region, neck or head (including headache).

b. Pain and tenderness on palpation of the affected area as above, or palpation may reproduce their symptoms.

2. Peripheral findings

a. Arm or hand symptoms consistent with central nerve compression. Symptoms may include numbness, pain, paraesthesia, vasomotor changes, and weakness (with muscle wasting in extreme cases).

b. Peripheral symptoms are often exacerbated by manoeuvres that either narrow the thoracic outlet (lifting the arms overhead) or stretch the brachial plexus (dangling; often driving or walking/running).

c. Palpation of the affected area (scalene triangle or pectoralis minor insertion site) often reproduces the patient's peripheral symptoms.

d. Provocative manoeuvres that are believed to narrow the scalene triangle (EAST) or to stretch the brachial plexus (ULTT) (both described later) can produce or worsen their peripheral symptoms.

3. Absence

Absence of another reasonably likely diagnosis (cervical disk disease, shoulder disease, carpal tunnel syndrome, chronic regional pain syndrome, brachial neuritis) that might explain/produce the majority of the patient's symptoms. Cervical nerve root pathology would be the biggest suspect and peripheral nerve entrapment. However, one would expect positive findings on imaging and specific investigations. Cervical nerve root compression would also present with more specific dermatomal and myotomal presentation accompanied with positive imaging findings.

4. Positive response to scalene block or injection (7)

This is preferential but may not be available to everyone depending on hospitals/specialists/cost.

Sanders et al. reported that among 50

Table 2: CORE-TOS clinical diagnostic criteria for neurogenic TOS
Ohman JW, Thompson RW. Thoracic outlet syndrome in the overhead athlete: diagnosis and treatment recommendations. Current Reviews in Musculoskeletal Medicine 2020;13(4):457–471 (6*)

Upper extremity symptoms extending beyond the distribution of a single cervical nerve root or peripheral nerve, present for at least 12 weeks, not satisfactorily explained by another condition, AND meeting at least 1 criterion in at least 4 of the following 5 categories:	
1. Principal symptoms	
1a.	Pain in the neck, upper back, shoulder, arm and/or hand
1b.	Numbness, paraesthesia, and/or weakness in the arm, hand, or digits
2. Symptom characteristics	
2a.	Pain/paraesthesia/weakness exacerbated by elevated arm positions
2b.	Pain/paraesthesia/weakness exacerbated by prolonged or repetitive arm/hand use, including prolonged work on a keyboard or other repetitive strain tasks
2c.	Pain/paraesthesia radiate down the arm from the supraclavicular or infraclavicular spaces
3. Clinical history	
3a.	Symptoms began after occupational, recreational, or accidental injury of the head, neck, or upper extremity, including repetitive upper extremity strain or overuse
3b.	Previous ipsilateral clavicle or first rib fracture, or known cervical rib
3c.	Previous cervical spine or ipsilateral peripheral nerve surgery without sustained improvement in symptoms
3d.	Previous conservative or surgical treatment for ipsilateral TOS
4. Physical examination	
4a.	Local tenderness on palpation over the scalene triangle and/or subcoracoid space
4b.	Arm/hand/digit paraesthesia on palpation over the scalene triangle and/or subcoracoid space
4c.	Objectively weak handgrip, intrinsic muscles, or digit 5, or thenar/hypothenar atrophy
5. Provocative manoeuvres	
5a.	Positive 3-minute elevated arm stress test (EAST)
5b.	Positive upper limb tension test (ULTT)

patients, symptom distribution in nTOS included upper-extremity paraesthesia (98%), trapezius pain (92%), shoulder pain (88%), arm pain (88%), neck pain (88%), supraclavicular pain (76%), occipital headache (76%), chest pain (72%), and paraesthesia (98%) in all five fingers (58%), fourth and fifth fingers (26%), first through third fingers (14%) (8*).

A recent publication of standardised clinical diagnostic criteria for nTOS (Table 2) has brought more uniformity and recognition to the diagnosis of this condition (1*,6*,9*).

In addition to presenting with the criteria discussed above, there are some additional tools that may be helpful to diagnose nTOS. Although these factors are not required for diagnosis, most patients have prolonged symptoms (>6 months), deteriorate over time, and have a history of trauma or repetitive overhead action.

The Cervical Brachial Symptom Questionnaire (CBSQ) (downloadable at Link 2) can help differentiate between cervical and thoracic outlet causes of arm symptoms (10*). To score this, add together the sum of all 12 numerical questions. A patient with no disability will score 0; one with maximal disability will score 120 (10*).

The Shortened Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) questionnaire (downloadable at Link 3) may also be a helpful tool. Scoring instructions are at the bottom of the questionnaire. To score, add the sum of responses, divide by the number of responses, and subtract 1 from this, then multiply by 25 (a minimum of 10 of the 11 items must be answered to score the instrument). A patient with no disability will score 0; one who has maximal disability will score 100. The *Quick*DASH questionnaire may be used free of charge for clinical purposes, but users are asked to read the conditions of use and copyright disclaimer.

Subjective Assessment

You should have thorough documentation of as many of the following factors as possible (1*).

- Symptoms – pain, numbness, tingling and weakness.
- The type and distribution of the symptoms.
- What causes or exacerbates the symptoms – specifically overhead activities, driving, exercising and activities of daily living.
- Sleeping difficulties, pain at night.
- Temporal pattern of symptoms – how long have they been present, waxing and waning versus steady worsening (or plateauing).
- History of trauma, with single episode vs repetitive motion injury clearly described and differentiated.
- Duration of symptoms – as many patients are only diagnosed after 60 months (5 years!) you need to establish how long this has been present.
- Previous treatment and results – there may be a long list of interventions, surgeries and doctors (patients have often seen six different types of doctors or medical professionals).
- Occupation, with specific description of any potential relevant factors (prolonged keyboarding, arms overhead).
- Relevant hobbies, sports.
- Arm dominance.
- Completed the CBSQ/*Quick*DASH assessments.

In the high-level athlete, symptoms can fluctuate, which often leads to a long interval from symptom onset to clinical diagnosis. Periods of minimal symptoms often correspond to periods of rest in their training/competing schedule or even normal day-to-day activities, whereas exacerbation of symptoms may correlate with increased training loads. High-performance athletes tend to have minimal symptoms at rest and only be symptomatic during or after athletic activities; this is in comparison to nTOS patients in the general population who may have significant symptoms at rest (11). Athletes' 'symptoms' may be described differently from the general population – for example they may complain of significant fatigue, or heaviness in their arms. They may complain that they are unable to perform as many repetitions (or diminished speed, power and force)

Video 2: Tinel Sign | Thoracic Outlet Syndrome (TOS) (Courtesy of YouTube user Physiotutors)
https://youtu.be/jvWvW3Bk4R8

Video 3: Tinel Sign Elbow | Cubital Tunnel Syndrome (Courtesy of YouTube user Physiotutors)
https://youtu.be/ASRatLbu8i0

Video 4: Tinel Sign of the Wrist | Carpal Tunnel Syndrome (CTS) (Courtesy of YouTube user Physiotutors)
https://youtu.be/SOHdFU3hllE

Video 5: Spurling's Test | Cervical Radicular Syndrome (Courtesy of YouTube user Physiotutors)
https://youtu.be/3ZSNdv0o0yk

when throwing, bowling, serving, weight lifting or shooting hoops for example. Using these semi-objective metrics may be useful in uncovering (and monitoring progress) in nTOS for the overhead athlete (6*,12*).

Objective Examination

1. Observation and Palpation (1*)

This should involve checking:

- posture and any abnormal movement;
- scapular posture;
- spontaneous use of affected arm;
- presence or absence of visible hand (thenar, hypothenar, or interosseous) muscle atrophy compared with contralateral side;
- presence or absence of Tinel signs along the radial, ulnar, and median nerves (Videos 2–4);
- point tenderness at scalene triangle or pectoralis minor insertion site;
- axillary tenderness;
- subjective swelling or tightness, asymmetry at the base of the neck;
- reproduction of arm or hand symptoms on palpation over supraclavicular scalene triangle or subcoracoid pectoralis minor muscle insertion site; and
- any other manoeuvres performed to exclude other diagnoses (eg. the Spurling test can be used to rule out cervical radiculopathy) (Video 5) (13).

PRESENTATION OF TOS SYMPTOMS VARIES FROM PATIENT TO PATIENT

2. Neurological Examination

The neurological examination should include assessing muscle wasting, testing reflexes and looking at sensation both pinprick and thermal. Often patients with suspected nTOS are sent for investigations including magnetic resonance imaging (MRI), magnetic resonance neurography and nerve conduction studies only to return with normal findings (3*,4*,5*), which can become very frustrating and confusing. Traditionally, patients with suspected neuropathies undergo neurological investigations including light touch, muscle strength and reflex testing. These tests, along with nerve conduction studies, focus solely on the function of large-diameter nerve fibres; however, recent work suggests that small-diameter fibres are often affected in peripheral neuropathies and nerve compression. These small-diameter fibres may deteriorate before a compromise in large-fibre function becomes apparent (14*,15).

In people with suspected neuropathies, neglecting to examine small-fibre function may result in the underreporting of sensory changes (16*). Quantitative sensory testing (QST) can be used to assess the functional properties of small fibres. Specifically, warm/cold detection thresholds and the perception of pinprick stimuli are known to examine the function of the C- and A-delta fibres (16*). Although QST is a great analysis of small-fibre function, it does, however, require costly equipment and is often not available to clinicians outside specialised health centres. Therefore, the use of simple bedside tests to determine small-fibre degeneration is clinically very relevant, and studies have proven them to correlate significantly to QST, suggesting that they can be a reliable tool for assessing sensory dysfunction (17*,18*). There are several tests that can be used, and these are described below.

- Neurotip (Owen Mumford Ltd) is used to establish the ability to detect sharp stimuli. The Neurotip is first applied to the ventral forearm (innervated by the median nerve proximal to the carpal tunnel) and then to the palmar tip of the index finger (affected median nerve territory). The Neurotip is applied with pressure sufficient to produce blanching of the skin, but without penetration. The patient is asked whether the sharpness of these two stimulations are comparable. A reduction in sharpness sensation at the fingertip is rated as a reduced mechanical pain threshold. A toothpick can be used to determine sharp sensations. The toothpick can be gently pressed over the lateral upper arm innervated by the radial nerve, and then over the palmar aspect of the index fingertip. Patients are asked to compare the sharpness of these two pricks. Comparable to the Neurotip, a reduced sharpness in the fingertip was rated as a reduced mechanical pain (nociception) threshold (17*).
- A metal coin can be used to determine the ability to discriminate thermal sensations. A coin held at room temperature is placed over the lateral upper arm. The coin is then placed over the palmar aspect of the index fingertip, and the patient is asked whether the temperature of the coin was comparable between the two sites. Patients are asked to compare the perceived temperature of the coin at the fingertip to that at the lateral upper arm (the same, colder, or warmer). Metal is a good heat conductor and is perceived as 'cold' at room temperature. Thus, a perception of 'warmer or less cold' at the fingertip is rated as a deficit in cold detection (17*).
- The same procedure is repeated with a coin that has been placed in the clinicians pocket for at least 30 minutes. This coin is perceived as neutral or slightly warm in a healthy population. A perception of 'colder or less warm' over the palmar tip of the index finger compared to the lateral upper arm is interpreted as a deficit in warm detection (17*).
- If both warm and cold detection thresholds are normal then there is a strong possibility there is no small-fibre degeneration. If the patient has reduced pinprick sensation, there is a strong possibility of small-fibre degeneration. However, the issue with pinprick sensation being

normal is that it doesn't necessarily rule out nerve involvement and so it is critical that both pinprick and thermal testing are performed in the assessment to get a better neurological picture (17*,18*).

3. Provocative Tests

There are multiple tests that can be performed to assess TOS, including the Adson manoeuvre, the Wright manoeuvre, and the Halsted manoeuvre (5*). Take care to choose the correct provocative test as false-positive results are common in provocative testing for TOS with, for example, the Adson test (2%), costoclavicular test (10%), and Wright tests (16.5%) (19). Therefore, two reliable tests stipulated for assessing nTOS are the elevated arm stress test (EAST), commonly also referred to in literature as the Roos test, and the second test being the upper limb tension test (ULTT) (1*).

- Elevated arm stress test (EAST) (Video 6). This test is used to assess symptoms caused by narrowing of the scalene triangle. The test is positive if pain, paraesthesia, heaviness or weakness are provoked locally or distally, so essentially reproducing the patient's symptoms. The word 'stress' in the test name refers to the fact that the arms are abducted to 90°, elbows bent to 90°, and brought backwards – the surrender position. The hands are usually briskly opened and closed for up to 3 minutes in this position, although this is not strictly necessary. The patient can stop if symptoms are provoked before the end of the 3-minute test duration. This test is reported to have 90% sensitivity (1*). Two very important points to note when conducting the test are the timing and the positioning. The patient must be absolutely up in the surrender position, with slight extension of the shoulder putting stress on the thoracic outlet region. As the patient fatigues (3 minutes is a long time!), their arms will drop and move forward, so maintaining positioning is crucial. One can imagine if the patient drops their arms down or lets them drift forward, then potentially they could have a false-negative result with this test. The second point is that the mean time to onset of symptoms is 1 minute 42 seconds – again that's longer than one thinks. To gain true value from the test it must be timed and the patient must not stop before provocation of symptoms or the end of the 3-minute time limit (5*,6*,20*). Results should be recorded as (1*):
  - Time (in seconds) to onset of symptoms and what/where they are.
  - Time (in seconds) to dropping arm/unable to complete test.
- Upper limb tension test (ULTT). See Figure Upper limb tension test (ULTT) from Sanders et al. at Link 4 (8*). This is a modified ULTT in that the patient is sitting up and executing the manoeuvres actively rather than having the examiner perform them passively. Carrying out the test in this way permits both limbs to be tested simultaneously and permits the asymptomatic side to serve as a control for the symptomatic one (8*). The modified ULTT is performed with three

Video 6: Roos/Elevated Arm Stress Test | Thoracic Outlet Syndrome (TOS) (Courtesy of YouTube user Physiotutors)
https://youtu.be/0oGGdcQsBKY

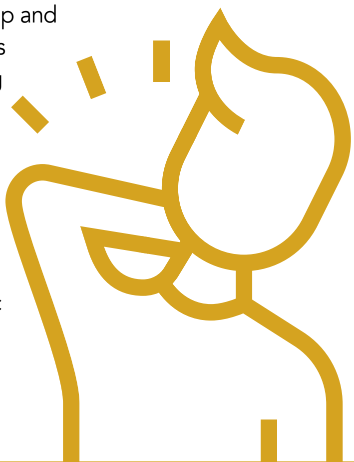


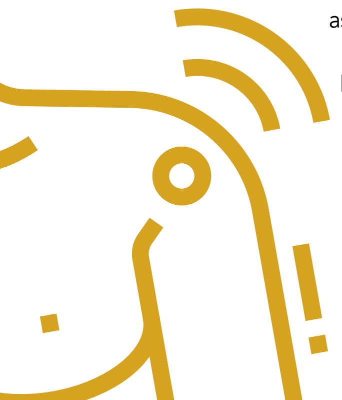
Table 3: Differential diagnoses for thoracic outlet syndrome and their distinguishing clinical features
Chang MC, Kim DH. Essentials of thoracic outlet syndrome: a narrative review. World Journal of Clinical Cases 2021;9(21):5804–5811 (5*)

Disorder	Distinguishing features
Raynaud's syndrome	Cold fingers, colour changes in the skin in response to cold or stress that are relieved by warmth
Vasculitis	Severe sudden-onset pain involving more than one limb, elevated C-reactive protein level, skin lesion (eg. purpura, petechiae, ulcer)
Rotator cuff tear	Pain during shoulder movement that is easily differentiated by ultrasound
Cervical radiculopathy	Acute pain (disc rupture), insidious onset (spinal stenosis), spurling sign (+), denervating potential of cervical paraspinalis on electromyography
Cubital tunnel syndrome	Tinel sign (+) over cubital tunnel; differentiated by nerve conduction study
Guyon's canal syndrome	Tinel sign (+) over Guyon's canal; differentiated by nerve conduction study
Neuralgic amyotrophy	Extreme sudden-onset pain followed by rapid motor weakness and atrophy
Pancoast tumour	Pain in the shoulder radiating to the inner part of the scapula, possible Horner syndrome, tumour on the apex of the lung
Complex regional pain syndrome	Diffuse pain, predominant vasomotor features, history of stroke, trauma, or peripheral nerve injury

THE THORACIC OUTLET IS AN ANATOMICAL AREA IN THE LOWER NECK INVOLVING THE INTERSCALENE TRIANGLE, THE COSTOCLAVICULAR SPACE, AND THE PECTORALIS MINOR SPACE manoeuvres in succession as follows:

- Position 1: abduct both arms to 90° with the elbows straight.
- Position 2: dorsiflex both wrists.
- Position 3: tilt the head to one side, ear to shoulder. The head is then tilted to the other side. Positions 1 and 2 elicit symptoms on the ipsilateral side, and position 3 elicits symptoms on the contralateral side.

Pain down the arm, especially around the elbow, and/or paraesthesia in the hand is a positive response. Production of symptoms in position 1 is the strongest positive test with increased symptoms in positions 2 and 3. The weakest response would be onset of symptoms only in position 3. On rare occasions for patients with severe pain at rest, this test can be performed passively by the examiner moving the arm through each position (1*,8*). A positive ULTT is not pathognomonic of nTOS; however, it indicates compression of the nerve roots or the branches of the brachial plexus in one of three areas: the thoracic outlet space, pectoralis minor space, or in the cervical spine. In diagnosis of nTOS, a positive ULTT should be viewed together with results from other tests and assessment (discussed above) (8*).



Electrodiagnostic and brachial plexus imaging studies are not required for diagnosing nTOS, unless another disease is suspected. Brachial plexus imaging studies (including ultrasound, computed tomography, MRI) have not yet been shown to be correlated with outcomes in nTOS, although imaging of the cervical spine may be useful to eliminate other conditions (1*,5*).

Finally, the patients should be asked to rate their *global overall* disability. TOS disability scale (0 being none, 10 being complete), establishes the impact of not just pain related to TOS symptoms but also the effect on home, work, school, social and sports activities (1*).

A thorough data collection/assessment sheet for patients with nTOS, encompassing all of the factors, tests and TOS disability scale, as discussed in this section of clinical assessment and diagnosis, should be utilised. The Neurogenic TOS: First Visit datasheet developed by Illig et al. is available to download from their paper at Appendix III (Link 5) (1*).

Before moving on to treatment, a judgment of severity should be made on two axes. Firstly, the degree of suspicion that nTOS exists, ranked as low, medium, or high, determined by the clinician/physical therapist, is represented along the *x*-axis. Secondly, the degree of severity, as mild (low), moderate (medium), or severe (high) derived from the patient's perspective of how severely the symptoms affect his or her life is represented along the *y*-axis (1*). The two-axis severity tool can be downloaded from Figure 8 from Illig et al. (Link 6) (1*).

NEUROGENIC TOS IS THE MOST COMMON OF THE THREE TYPES OF TOS, REPRESENTING ABOUT 95% OF CASES

Differential Diagnosis

Owing to similarity in symptoms with other disorders, TOS is frequently misdiagnosed. Other disorders, such as cervical radiculopathy, inflammatory neuropathy, and other nerve entrapment syndromes, should be excluded in order to confirm TOS (5*). The disorders (along with their distinguishing clinical features) that should be ruled out before confirming the diagnosis of nTOS are described in table above (Table 3).

Conservative Management of nTOS

The main features of the initial stages of treatment for nTOS involves (i) rest of the affected extremity; (ii) physical therapy to release the scalene muscles and decompress the scalene triangle and subcoracoid spaces; and (iii) the use of muscle relaxants and anti-inflammatory or analgesic medications.

Many patients with nTOS symptoms gain relief through conservative treatment, and as such physical therapy is a first-line treatment for this condition. The usual initial rehabilitation therapies include (i) patient education of posture, relaxation techniques, and weight management; (ii) exercise including stretching and strengthening of targeted muscles, and (iii) activity modification. The physical therapist has a capital role and is the guarantor of the effectiveness of the initial treatment. One study demonstrated symptomatic relief in more than 60% of patients with nTOS following 6 months of physical therapy (21*). Even in patients with substantial levels of pre-treatment disability, physical therapy alone can be effective in 31% of patients (9*).

Oral pain medications can be used to relieve neuropathic pain. Botulinum toxin injections into the scalene muscles and/or pectoralis muscle and corticosteroid injections into the pathologic areas have also been shown to be useful for managing nTOS (2*,5*,22*). If patients do not respond to these conservative treatments, surgical treatment, such as first rib and/or cervical rib resection, may be considered (2*,9*).

When physical therapy and conservative management is deemed insufficient, then surgical intervention can provide substantial symptom improvement in approximately 90% of patients (9*). It is important, however, to ensure an adequate trial of conservative management before considering surgery. Some studies have elected for surgery following inadequate improvement in symptoms and disability following 4–6 weeks (9*) of conservative management, whereas other research suggests a longer trial of 4–6 months before considering surgical intervention (23*). The initial physical therapy treatment is invaluable even for patients considered likely to require surgical treatment, because the physical therapy sessions allow the therapist to establish a baseline status for the individual patient, teach nTOS-specific protocols, help manage expectations for treatment, educate on pain science and better anticipate specific needs that might arise during postoperative rehabilitation (9*). This point of waiting for surgery only after 'failed' conservative management may be contentious. If there is any evidence of nerve function compromise, especially gross changes, as part of your assessment, then the recommendation may be for early referral to a surgeon as this may give those patients the best chance of a successful outcome.

Physical Therapy

Traditionally, physical therapy focuses on exercises aimed at creating and increasing the space between the first rib and clavicle, and decrease the tensile load of the upper limb. Postural retraining and optimising diaphragmatic breathing, to reduce accessory muscle over use that can contribute to compression of the thoracic outlet, should be targeted (22*). Research by Balderman et al. showed that 27% of patients with nTOS obtained satisfactory improvement with physical therapy alone (9*), whereas another study demonstrated symptomatic relief in 25 of 42 patients after 6 months of physical therapy (21*).

More recently, work by Collins et al. has shown that physical therapists are applying novel techniques in neuroscience and cognitive behavioural therapy in the form of informed physical therapy for improving outcomes (24). This entails physical therapists striving to improve patient function and symptoms through several techniques that target various domains including:

- external support, such as a shoulder girdle or sling used in the initial stages, short term, to improve symptoms;
- function and ergonomics, such as posture training and changes to home or work space ergonomics;
- neural glides;
- psychologically informed physical therapy;
- pain-science education; and
- movement pattern retraining, which allows for a greater tolerance to functional activities and can have a positive impact on quality of life (24).

Scapular protraction and head forward posture tightens the anterior and middle scalenes, sternocleidomastoid, trapezius, levator scapulae, pectoralis muscles, suboccipital muscles, and elongates the middle and lower trapezius muscles. This, in turn, narrows the thoraco-coraco-pectoral space. These muscles, in a shortened or lengthened position, are at a mechanical disadvantage. Posture correction includes reducing forward head posture and encouraging scapular retraction, which opens up the thoraco-coraco-pectoral space (19).

Release of tight structures possibly contributing to compression in the thoracic outlet can be done using massage, manual therapy techniques, muscle energy techniques, active release techniques, mobilisation and manipulation. Relaxation and pain management can be addressed using massage techniques as well as heat and transcutaneous electrical stimulations as well as any other form of relaxation technique the patient may choose (tai-chi, yoga, meditation) (25). Passive and active neuro-dynamic techniques, avoiding amplitudes that trigger painful symptoms should be included in treatment. Stretching of scalene muscles, sternocleidomastoid muscles, upper and middle trapezius, pectoral muscles, shoulder stabilisers and para-vertebral muscles can be prescribed (Video 7) (25).

Evaluation of joint mobility, scapular kinematics and parascapular control of the rhomboids, serratus anterior, and the middle/lower trapezius is necessary. Frequently patients present with weakness in the lower scapular stabilisers and hypertrophy in scapular elevators. This is due to overused arm movements, especially the upper trapezius, levator scapulae and upper rhomboids (19).

Muscular strengthening is generally to be avoided except for all the para-vertebral muscles, serratus and small pectoralis muscles (the muscles that open the costoclavicular interspace). This active work must not trigger pain or neural sensations (25). Strengthening is generally discouraged as shortening or spasm of the muscles around the neck may exacerbate TOS symptoms. However, weak muscles of the cervical spine and shoulder girdle may be contributing to TOS symptoms through spasm developed from muscle fatigue or poor postural alignment. Individualised and supervised exercise therapy with ongoing posture correction and proprioception training will be beneficial (25). Emphasis should be on stretching the muscles that close the thoracic outlet (such as the scalene and pectoralis muscles) and strengthening the muscles that open the thoracic outlet (such as the scapular

Video 7: Thoracic Outlet Syndrome Treatment | Stretches (Courtesy of YouTube user Physiotutors)
https://youtu.be/eONCDrH5vB0

Table 4: Instructions for graduated resisted shoulder elevation exercises
Adapted from Kenny R et al. Thoracic outlet syndrome: a useful exercise treatment option. American Journal of Surgery 1993;165(2):282–283 (26). © Elsevier Inc 1993

Exercise: elevate shoulders and hold for count of 5, then relax shoulders. Repeat as outlined below

Week 1:	**No weights**
Day 1	15 exercises, 5 times daily
Day 2	15 exercises, 5 times daily
Day 3	15 exercises, 6 times daily
Day 4–7	20 exercises, 6 times daily
Week 2:	**1.25kg weight held in each hand**
Day 1	10 exercises, 5 times daily
Day 2	15 exercises, 5 times daily
Day 3	20 exercises, 5 times daily
Day 4-7	20 exercises, 6 times daily
Week 3:	**2.5kg weight held in each hand**
Day 1	10 exercises, 5 times daily
Day 2	15 exercises, 5 times daily
Day 3	20 exercises, 5 times daily
Day 4–7	20 exercises, 6 times daily

●● PHYSICAL THERAPY CAN SIGNIFICANTLY IMPROVE PATIENT SYMPTOMS ACROSS ALL PARAMETERS ●●

stabilising muscles, the rhomboids and the middle/lower trapezius muscles) (19). Targeted, progressive strengthening aims to improve muscular endurance with low weight and a high number of repetitions (19).

Albeit an older study with a small sample size, research by Kenny et al. showed that a simple graded exercise programme (Table 4) significantly improved patient symptoms across all parameters (pain in hand, arm and neck, pins and needles, and weakness in the upper limb) after 3 weeks (26).

At all visits for nTOS, as many as possible of the following should be reported:

- description and severity of interval symptoms, including impact on work, school, recreation, and daily activities;
- extent of interval involvement in physical therapy and progress achieved;
- adjunctive procedures or interventions performed;
- current medications, including opioid narcotics;
- results from scoring instruments – *Quick*DASH, CBSQ, TOS disability; and
- physical examination.

A thorough data collection sheet for patients with nTOS, encompassing all of the above factors should be utilised. The Neurogenic TOS Therapy datasheet developed by Illig et al. is available to download at Appendix IV (Link 7) (1*). Results should be reported specifically at 3, 6, 12, and 24 months after the initiation of any therapy or surgery.

Ongoing symptoms of nTOS at any interval after treatment are characterised as either:

- persistent (no improvement after previous treatment); or
- recurrent (return of symptoms of equal or greater severity than previously present, after a period of at least 3 months since last treatment).

The majority of instances of recurrent nTOS occur within 12 to 18 months after surgical treatment, after which recurrence is relatively uncommon.

If this is a follow-up appointment after some time (be it a break from treatment, following surgery or a recurrence), thorough documentation should be done. The Neurogenic TOS Follow-Up datasheet developed by Illig et al. is available to download at Appendix V (Link 8) (1*).

Surgical Intervention in nTOS

Most surgical candidates exhibit nTOS with uncontrolled pain, inadequate response to conservative management, or progressively worsening upper-extremity weakness (2*). The surgery of choice is a first rib resection, often combined with a scalenectomy or scalenotomy, aimed at brachial plexus decompression, and can be performed by thoracic surgeons, neurosurgeons, orthopaedic surgeons and plastic surgeons. Brachial plexus decompression, by removal of the first rib, can be performed via three approaches: transaxillary, supraclavicular and infraclavicular techniques. Each approach has achieved good outcomes, with no definitively superior technique (2*,27*). Overall outcomes from surgical decompression are very positive. Following surgical intervention, 95% of patients with nTOS report 'excellent' results (2*,28*).

Research by Shutze et al. reported satisfaction with outcomes in a survey of competitive athletes who had undergone surgical treatment, namely first rib resection and scalenectomy (FRRS), for nTOS (27*). There was an improvement in pain medication use in 96% and resolution of symptoms in 82%, with 75% reporting that they would undergo contralateral decompression if necessary. Ninety-four percent of athletes stated that they were unlimited in performing standard day-to-day activities, and 70% of these athletes had returned to the same or better subjective levels of activity. Half of the individuals reached that goal 1 year after surgery (27*).

Postoperative Rehabilitation

As with most surgical interventions, immediate postoperative care after thoracic outlet decompression is focused around pain control, maintenance of full range of motion at the shoulder and the neck, optimisation of wound healing, and initiation of light physical therapy to avoid muscle spasm (6*). From here, physical therapy is progressed over the next 3–4 weeks, focusing on passive and assisted exercises based on shoulder range of motion, avoidance of strength training at this stage, 'nerve glides' for neural mobilisation, maintenance and improvement of posture, addressing scapular kinematics, teaching diaphragmatic breathing patterns, and maintaining general conditioning. At approximately 8 weeks, resistance strength training for the mid and lower trapezius, serratus anterior, and rotator cuff muscles begins, as well as continued efforts to maintain full range of motion and corrected movement patterns. For an athlete, gentle throwing or overhead activities can begin. At the 12-week mark, a more formal graduated throwing/overhead sporting activity programme may begin and progress as tolerated (6*).

It is critical that all of these steps work in concert during the rehabilitation process, as attempts to rush the process may lead to the development of excessive muscle spasm with subsequent perineural scar tissue deposition and increased risk of recurrent nTOS symptoms (6*). Full rehabilitation and return to high-level athletic competition often takes 9–12 months following surgery.

An overview of postoperative rehabilitation for neurogenic TOS includes the following stages (6*).

Stage I: Inpatient

- Hospital length of stay: 3–5 days.
- Do self-directed exercises (cervical and shoulder ROM).
- Follow-up visit with surgeon, postoperative day 5–7, drain removal.

Stage II: First Postoperative Month

- Protect surgical tissues to promote

healing and minimise muscle spasm (propping arm with pillows while sitting and sleeping, ice, medications).
- Maintain cervical and glenohumeral range of motion.
- Begin light conditioning activity (walking, bicycle).

Stage III: Second postoperative month
- Have physical therapy, 1–2 sessions per week.
- Continue pain management.
- Attend to posture (head, shoulders, and scapulae), monitor for scapular winging.
- Begin light neural mobilisations.
- Begin gentle stretching of levator, upper trapezius, and pectoral muscles.
- Begin movement of scapula into upward rotation and elevation.
- Attend to breathing pattern, teaching diaphragmatic breathing.
- Continue conditioning activity (walking, bicycle, elliptical, treadmill) but avoid vigorous use of involved upper limb.
- Begin activities of daily living, ergonomics, work environment.
- Cautions: no strengthening including use of weights or bands, avoid manual therapies that may irritate sensitive healing tissue, no immersion in water until incisions fully healed.

Stage IV: Third and Fourth Postoperative Months
- Continue physical therapy, 1–2 sessions per week.
- Continue symptom management, may introduce manual therapies.
- Continue conditioning activity (bicycling, walking, elliptical, treadmill).
- Begin strengthening mid and lower trapezius, serratus anterior, and rotator cuff muscles.
- Increase range of motion of upper limb, begin throwing motion, optimise movement patterns.
- Introduce gentle throwing and progress as tolerated.

Stage V: Fourth to Sixth Postoperative Months
- Follow a supervised throwing programme, progressing as tolerated (the one below is for baseball pitchers, but can be modified according to sport/activity, for example number of shots in basketball, number of serves, bowling in cricket, volleyball shots instead of number of throws, as long as it's slow and progressive):
  - step 1: 1×25 throws at 60ft
  - step 2: 2×25 throws at 60ft
  - step 3: 1×25 throws at 60ft, 1×25 throws at 90ft
  - step 4: 1×30 throws at 60ft, 1×25 throws at 90ft
  - step 5: 1×30 throws at 60ft, 1×25 throws at 90ft
  - step 6: 1×30 throws at 90ft, 1×25 throws at 120ft
  - step 7: 2×20 throws at 120ft
  - step 8: 1×20 throws at 120ft, 1×20 throws at 150ft
  - step 9: 1×20 throws at 150ft, 10 pitches from mound
  - step 10: long toss, 35-pitch bullpen session
- Gradually increase activity toward unrestricted return to competition at 6 to 9 months.

Evaluating the athlete's range of motion, muscle strength, and functional athletic ability should be included when considering return to sport. Sport-specific testing is recommended to recreate similar athletic activities. Considering mental readiness to return to play is included in the safety evaluation, especially for contact sports. Finally, open communication with athletic trainers, coaches, team physicians, and other medical personnel can help gather information necessary for return-to-play decision-making.

Conclusion

We may encounter many patients on a daily basis in clinic that present with upper limb pain with or without motor weakness. Of these, only a few are likely to have TOS. To ensure diagnostic accuracy and appropriate treatment, clinicians should have better knowledge of TOS. Too many patients are remaining undiagnosed, living with symptomology, for too long when accurate diagnosis and appropriate treatment could change their lives. Early identification and treatment of TOS provide the greatest opportunity for optimal recovery. Regrettably, the throng of non-specific symptoms, which makes diagnosis challenging, can delay treatment and increase the risk of the development of complications.

Despite advances, substantial controversy regarding the diagnosis remains. This is evidenced by the lack of objective findings surrounding nTOS, the most common type of TOS. The challenges associated with diagnosis complicate the selection of the appropriate treatment options.

As discussed in this article, the North American Society for Vascular Surgery reporting standards for nTOS (1*) were published in 2016 to produce greater consistency in diagnosis and management. Since then a large cohort study has shown that by using these guidelines more than 56% of patients were confirmed with an accurate diagnosis and referred for treatment. Of these 40% had successful physical therapy treatment and 60% successful surgical intervention (29). Significant improvements in disability scores were seen across all patients. A multidisciplinary team guiding patients, using diagnostic criteria and reporting standards discussed in this article, might significantly benefit patient outcomes.

References

Owing to space limitations in the print version, the references that accompany this article are available at the following link and are also appended to the end of the article in the web and mobile versions. Click here to access the references https://bit.ly/3KFLLv7

RELATED CONTENT

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- **The Brain, Movement and Pain: Part 1 [Article]** https://bit.ly/3fzr99G
- **The Brain, Movement and Pain: Part 2 [Article]** https://bit.ly/3vgvntv

DISCUSSIONS

- In your years of practice do you recall an individual that may have presented with the necessary criteria for nTOS diagnosis that could have been 'missed'?
- How confident are you in performing the simple bedside clinical tests (Neurotip and coin) in your neurological examination?
- Do you have a specific technique, stretch or exercise that works well in relieving thoracic outlet symptoms?

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LINK 1: Figure 1: Thoracic outlet and relevant anatomy in Jones et al. Thoracic outlet syndrome: a comprehensive review of pathophysiology, diagnosis, and treatment. Pain and Therapy 2019;8(1):5–18 (2*) https://bit.ly/36sDVGc

LINK 2: Cervical Brachial Symptom Questionnaire (CBSQ), developed by Jordan et al. Differentiation of thoracic outlet syndrome from treatment-resistant cervical brachial pain syndromes: development and utilization of a questionnaire, clinical examination and ultrasound evaluation. Pain Physician 2007;10(3):441–452 (10*) https://bit.ly/3pfblyF

LINK 3: Shortened Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) questionnaire, Institute for Work & Health 2006-2020, Toronto, ON Canada M5G 1S5 https://bit.ly/3lhXlfd

LINK 4: Figure Upper limb tension test (ULTT). Sanders et al. Diagnosis of thoracic outlet syndrome. Journal of Vascular Surgery 2007;46(3):601–604 (8*) https://bit.ly/3JSC3VA

LINK 5: Neurogenic TOS: First Visit datasheet. Developed by Illig et al., this is available to download from their paper at Appendix III. Illig KA, Donahue D, Duncan A et al. Reporting standards of the Society for Vascular Surgery for thoracic outlet syndrome. Journal of Vascular Surgery 2016;64(3):e23–35 (1*) https://bit.ly/3pbLYxy

LINK 6: Two-axis severity tool. Available at Figure 8 in Illig KA, Donahue D, Duncan A et al. Reporting standards of the Society for Vascular Surgery for thoracic outlet syndrome. Journal of Vascular Surgery 2016;64(3):e23–35 https://bit.ly/3p9VQbq

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KEY POINTS

- Thoracic outlet syndrome (TOS) comprises a group of potentially disabling conditions believed to be caused by compression of neurovascular structures supplying the upper extremity.
- Neurogenic TOS (nTOS), the most common type, can potentially result from neurovascular compression at three different anatomic levels: the interscalene triangle, the costoclavicular space, or the pectoralis minor space.
- nTOS can be caused by anatomical variations, trauma, repetitive stress, overhead activities, hypertrophy, muscle imbalance and poor postural alignment.
- Diagnosis of nTOS is based on the presence of at least three out of four criteria from local and peripheral findings of pain, numbness, weakness, paraesthesia and vasomotor changes, to positive provocative manoeuvres, the absence of another diagnosis and a positive scalene block or injection.
- Provocative tests include the elevated arm stress test (EAST), also known as the Roos test, and the upper limb tension test (ULTT).
- Simple bedside, cost-effective tests can determine small nerve fibre degeneration, a Neurotip or toothpick for sharp stimuli and a metal coin for thermal sensation.
- Physical therapy is a first-line treatment for nTOS.
- Rehabilitation therapy, including patient education (postural mechanics, relaxation techniques, and weight control), exercise (stretching and graded strengthening of targeted muscles), and activity modification are suggested and produce successful outcomes.
- Surgical intervention performing a first rib resection and scalenectomy (FRRS) produces excellent outcomes in the majority of patients.
- Postoperative physical therapy is critical, full rehabilitation and return to high-level athletic activity can take 9–12 months.

Thoracic Outlet Syndrome

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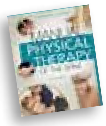

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